# Technical skills, disinterest and non-functional regulation: Barriers to building energy efficiency in Finland viewed by energy service companies

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# Technical skills, disinterest and non-functional regulation: Barriers to building energy efficiency in Finland viewed by energy service companies

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## Abstract

Energy inefficiency in the building stock is a substantial contributor to climate change. Integrated energy service companies (IESCs) have a potentially important role in improving energy efficiency. This paper presents a qualitative analysis of the energy efficiency barriers in the Finnish building sector based on data from interviews with twelve IESCs. Taking a novel supply side perspective, we place IESCs at the centre of the emerging energy services business ecosystem to identify the barriers and hindering factors (real world illustrations of barriers). From this perspective, we also examine cause-effect relationships between the hindering factors and the actors. Hindering factors, reported by IESCs, were categorised under a revised barrier taxonomy consisting of economic market failures and economic market, behavioural, organisational and institutional barriers. The most salient hindering factors—lack of technical skills, disinterest in energy efficiency improvements and non-functional regulation—were analysed with respect to ecosystem actors causing and affected by these factors. Public actors have a key role in overcoming these barriers, for instance, by creating new possibilities for entrants to take part in decision-making, increasing the functionality and practicality of policies and by providing up-to date energy efficiency information.

## Keywords

Energy services; barriers; energy efficiency; ecosystem; energy service company; buildings

# 1 Introduction

Energy inefficiency in a large part of the current building stock is a substantial contributor to climate change (Ástmarsson et al., 2013); and, also, in many countries to fuel poverty (Sorrell, 2015). In the European Union (EU), buildings account for approximately 40 percent of total energy consumption and 36 percent of greenhouse gas emissions; and have a high energy saving potential compared to other economic sectors (EU, 2016; Forsström et al., 2011). Therefore, building-level energy efficiency improvements and on-site renewable energy installations have significant climate change mitigation potential. Although reduction in energy consumption is commonly associated with technological change (e.g. insulation or ventilation) it can also stem from improved management or maintenance (Robinson et al., 2015). Yet, the current rate of energy performance improvements in buildings is still low in Europe (Sweatman, 2012; Meeus et al., 2012).

Many opportunities exist for cost-efficient measures to improve energy efficiency, which are not realised currently (Sorrell, 2015). The gap between the optimal energy efficiency improvements and the realised improvements is called the ’efficiency gap’ or the ’energy paradox’ (Jaffe and Stavins, 1994, Gillingham and Palmer, 2013). The underlying causes for the energy efficiency gap are known as *barriers* (Sorrell et al., 2000). Weber (1997, 834) was one of the first to address the structure of energy efficiency barriers, proposing a barrier model according to the methodological questions: “*What* is an obstacle to *whom* reaching what in energy conservation?” (emphasis in original). Sorrell et al. (2000) suggest that any fruitful empirical research must provide a clear understanding of the nature of the barriers, identify the relevant actor, and identify the relevant energy efficiency investment.

So far, seminal contributions (e.g. Sorrell et al., 2000; Gillingham et al., 2009; Nagesha and Balachandra, 2006) have focused on the identification and classification of energy efficiency barriers, with recent work (e.g. Chai and Yeo, 2012 and Cagno et al., 2013) taking a more actor centric approach.

The studies analysing barriers have focused on the failure of customers (e.g. households, public entities or companies) to make cost-efficient energy efficiency investments, which is evident in the numerous efficiency barrier models and taxonomies that have been developed. Some have identified supply side actors, especially energy service companies (ESCOs), as important for the transition towards low-carbon buildings (Robinson et al., 2015; Nolden and Sorrell, 2016), while only few studies have explored energy efficiency barriers from an energy service perspective. Duplessis et al., (2012) have, for example, explored the ways in which how markets for energy services can be supported. We address this gap in research regarding the analysis of barriers from the energy service company perspective, by empirically examining the views of integrated energy service companies (IESCs) in Finland due to their promising role in closing the energy efficiency gap. Moreover, we employ the concept of an "ecosystem" to have a brief look at how the barriers are caused by or affect other actors besides energy service companies.

Energy services have been suggested as a way to improve energy efficiency (Kindström and Ottosson 2016). Several definitions of energy services exist (see Kindström et al. 2017). Bertoldi et al. (2006, p. 1820) define them as ''a variety of activities, such as energy analysis and audits, energy management, project design and implementation, maintenance and operation, monitoring and evaluation of savings, property management, and energy and equipment supply." As integrated building-level approaches provide greater opportunities for improving energy efficiency (Levine et al., 2007), integrated energy services play an important role in achieving efficiency from a systemic perspective in contrast to individual incremental improvements. Such services through their nature have the potential to disrupt the existing system of planning and realising building energy use.

The potentially disruptive (Hannon, 2012) and increasingly popular (Duplessis et al., 2012) Energy Service Company (ESCo) business model typically offers "comprehensive contracts that include energy information and control systems, energy audits, installation, operation and maintenance of equipment, competitive finance, and fuel and electricity purchasing" (Sorrell, 2007, p507). Normally, such long-term service contracts (Hannon and Bolton, 2015) are defined to contain both finance and guarantee of energy and cost savings (Mahapatra et al., 2013) to allow clients to reduce energy costs, transfer risk and concentrate attention on core activities (Sorrell, 2007). The literature on integrated energy services does not yet provide a full account of the kinds of business models and their differences beyond the ESCo model (cf. Hannon and Bolton, 2015). Whilst the ESCo model is the most commonly mentioned *integrated energy service*, a variety of other 'one stop shop' energy service models also exist that do not include the guarantee and/or finance for the installed energy improvement measures (Mahapatra et al., 2013). Our study takes a broad scope on energy service companies and includes companies offering both ESCo and other integrated energy service models, enabling the inclusion of a greater number of companies involved in energy services.

We define IESCs as actors that provide holistic energy services which integrate a range of technical, financial and maintenance solutions to improve building energy efficiency and reduce energy demand in a cost-efficient way. Thus, we exclude companies providing single technology oriented services, such as heat pump installation or maintenance, from the study. Integrated energy services can comprise advice, consultancy, design, finance, metering, monitoring, management and optimisation, as well as the retail of diverse sets of technologies that through energy efficiency improvements and on-site renewable energy can result in reduced amount of purchased energy, cost of energy and reduced greenhouse gas emissions alongside improved living conditions. IESCs do not have to offer all the above-mentioned services; each typically has its own business model based on different services and customers. Figure 1 illustrates how integrated energy services can address different stages of a building's life-cycle, including design, construction, maintenance and renovation.

FIGURE 1 HERE

IESCs operate in an interdependent network of actors who are highly heterogeneous and specialised, and whose complementarity adds to value creation in the sector. Drawing from the literature on business ecosystems (e.g. Moore, 1996), we place IESCs at the centre of an emerging energy services business ecosystem, since value creation related to integrated energy services is beyond the capacity of any single actor. Whilst previous studies often stop at the identification of energy efficiency barriers, we identify the actors that cause and are affected by energy efficiency barriers based on the views of IESCs. Applying such an approach to the case of building energy efficiency can help to reconcile the relationships between barriers and actors throughout the emerging energy services ecosystem. With this in mind, we pose two questions:

1. What are the barriers and hindering factors that IESCs experience when they deal with the energy efficiency gap in the Finnish building sector?
2. Who are the actors in the emerging energy services ecosystem in Finland, and how is the direction of the barriers formed between the actors?

Finland is interesting country setting to study barriers for IESCs in building energy efficiency for several reasons. In Finland, energy consumption per capita is the second highest in the EU and is double the EU average for energy consumption; largely due to Finland’s energy intensive industry and cold climate. Yet, Finland was ranked among the top three countries in terms of progress in energy efficiency policy in the EU (Energy Efficiency Watch, 2013). Buildings account for 38 percent of the total energy consumption (space heating covering 25%) and 32 percent of greenhouse gas emissions (NEEAP-2 Finland 2011; Vehviläinen et al. 2010; Statistics Finland, 2016). It has been estimated that the emissions of the Finnish building stock could be decreased by approximately 50 percent by increasing the energy efficiency of the current building stock, but this would require a substantial increase to the refurbishment rate, which is currently 1-1.5 percent annually (Airaksinen et al. 2013). In Finland, the ESCO sector emerged approximately 15 years ago and, in 2014, there were three to five companies active in the Finnish market (Bertoldi et al. 2014). The penetration of the ESCO business model has been slow in Finland, due to customers being unaware of ESCOs, high transaction costs related to savings, and the general financial situation in Finland (Pätäri et al. 2016).

We aim at providing new insights into the analysis of building energy efficiency barriers in the Finnish building sector by taking a novel supply centric approach that accounts for the directional relationships of the actors causing and being affected by the barriers. Taking an IESC perspective, we are able to reveal the often neglected perspective of barriers that energy efficiency supply companies face. Analysis of interview data from twelve IESCs and two intermediaries allows us to identify the actors that are affected by, and cause, the barriers, going beyond current literature which focuses on the identification of barriers.

The paper is structured as follows. Section 2 provides an overview of the concept of business ecosystems and energy efficiency barrier models, taxonomies, categories and barriers. Section 3 describes the research design and methods and outlines the case of the emerging Finnish energy services ecosystem. Based on our typology of energy efficiency barriers, Section 4 identifies the factors hindering energy service companies in Finland. Section 5 provides a more detailed analysis of the salient hindering factors; lack of technical skill, disinterest in energy efficiency improvement and non-functional regulation. Section 6 discusses the benefits and limitation of a supply oriented approach to energy efficiency barriers and Section 7 provides policy recommendations.

# 2 Business ecosystems and energy efficiency barriers

## 2.1 Business ecosystems

To understand the cause-effect relationship between the barriers and the actors at the boundary of energy and construction sectors, the business ecosystem concept is employed. The concept is relevant for the study of integrated energy services in the building sector, as the nature of the services requires that IESCs create value by integrating various technical solutions (material and digital) into a service, and providing this service to the right customers at the right phase of a building's life cycle. The term 'ecosystem' is often used to refer to a network of interconnected organisations that are linked to, or operate around, a focal firm or platform (Thomas and Autio, 2012). Hence, IESCs are placed at the core of the emerging ecosystem, and business ecosystem layers are used as a frame to identify the actors in the ecosystem.

The business ecosystem concept was first outlined by Moore (1993), suggesting that a business ecosystem is an "economic community comprised of a number of interacting organisations and individuals, including suppliers, producers, competitors, customers and other stakeholders, that produces goods and services of value for the customers" (Moore, 1996, p. 26). Unlike linear value chains—where value creation is a linear process undertaken by upstream and downstream actors—in business ecosystems different companies with many horizontal relationships cooperate to jointly supply a product or service to customers (Clarysse et al., 2014). Ecosystems can comprise focal firms and actors such as suppliers, complementors, system integrators, distributors, advertisers, finance providers (e.g., venture capitalists, corporate investors, investment bankers, and angel investors), universities and research institutions, regulatory authorities and standard-setting bodies, the judiciary, and customers (Mäkinen and Dedehayir, 2012). As such, members of a business ecosystem "deliver value to end customers as an interrelated system of independent companies rather than independent companies" (Clarysse et al., 2014), allowing business ecosystems to create value that could not be created by a single firm alone (Adner, 2006).

Although Autio and Thomas (2014) suggest that all ecosystem concepts possess several elements (including a network of participants, a governance system and shared logic), in this paper, our analysis draws upon the network of participants component. Business ecosystems have been described as consisting of layers corresponding to varying levels of commitment (Moore 1993, 1996; Heikkilä and

Kuivaniemi, 2012). In the business ecosystem, *core businesses* are at the heart of the value creation process. These include core contributors, direct suppliers and distribution channels (Moore, 1996). The *extended business ecosystem* covers also the supply chain, including suppliers of suppliers, suppliers of complementary products or services, direct customers, customers of customers and standard setting bodies (Moore, 1996; Heikkilä and Kuivaniemi, 2012). The broader *business ecosystem* includes actors that, although not directly involved in the value creation process, have an effect on the ecosystem, such as competitors, government agencies and other regulatory authorities, investors, trade associations, labour organisations, research institutes and universities (Moore, 1996; Heikkilä and Kuivaniemi, 2012).

## 2.2 Energy efficiency barrier models and taxonomies

The lack of adequate energy efficiency improvements was first identified in the 1970's (Cagno et al., 2013). Later, Jaffe and Stavins (1994) explained the difference between the optimal energy efficiency level and the observed level as the 'energy efficiency gap'. The optimal level of energy efficiency can be defined in multiple ways, e.g. economic efficiency, technical efficiency, and social optimum. Sorrell et al. (2000, 11) defined energy efficiency barriers as "postulated mechanisms that inhibit investments in technologies that are both energy efficient and (apparently) economically efficient". In simple terms, barriers cause the energy efficiency gap.

Systematic studies of energy efficiency barriers are typically based on barrier taxonomies. The first barrier taxonomy was created by Blumstein et al. (1980) based on six categories (misplaced incentives, lack of information, regulation, market structure, financing and customs). Weber (1997) developed a taxonomy founded on the classification of market, behavioural, organisational and institutional barriers. Importantly, Sorrell et al. (2000) proposed a taxonomy which has been the basis of a majority of subsequent barriers studies. Building on Weber (1997), Sorrell et al. (2000) divide barriers into economic, behavioural, and organisational theory perspectives, and include sub-divisions and actual barriers.

More recently, Gillingham et al. (2009) addressed the gaps between economic and behavioural perspectives on barriers studies and classifications utilising behavioural economics. In recent endeavours to focus on the relationship between actors and barriers, Chai and Yeo (2012) have developed a framework to analyse company views on barriers and Cagno et al. (2013) developed a barrier taxonomy starting from a customer perspective, making the division between internal and external barriers based on actors and areas.

Empirical studies have utilised taxonomies with both qualitative and quantitative research methods and models. However, an established widely adopted single model does not exist to utilise taxonomies in empirical studies, and each study has usually developed a model of its own. For example, Nagesha and Balachandra (2006) form a taxonomy with five barrier groups and use it with the analytic hierarchy process model to prioritise the barriers based on their intensity, easiness of removal and impacts on energy efficiency, among other things. As another example, based on their taxonomy, Cagno et al. (2013) develop a qualitative model to study the origin of the barrier (internal or external), and how barriers impact decision-making and investments. Commonly, empirical barrier studies have not utilised taxonomies in their models, and have built them on empirical basis only.

Previous theoretical and empirical studies analysing barriers have mainly been concerned with the failure of customers (e.g. households, public entities or companies) to make the seemingly cost-efficient energy efficiency improvement investments (see Hausman, 1979; Stern and Aronson, 1984; Brown, 2001; Ástmarsson et al., 2013). For example, Gillingham and Palmer (2013) suggest that customers' decision-making characteristics and behaviour lead to the energy efficiency gap. This demand-side perspective is evident in the numerous models and taxonomies of energy efficiency barriers that have been developed (e.g. Sorrell et al., 2000; Gillingham et al., 2009; Cagno et al., 2013).

## 2.3 Categories and barriers

The structure of the barrier categories we utilise in this paper follows Weber (1997) and the barriers within these categories are principally based on Sorrell et al. (2000) and Gillingham et al. (2009), as illustrated in Table 1. We have included the institutional barriers category to the Sorrell et al. (2000) taxonomy to fully capture all barriers, loosely following the taxonomy of Nagesha and Balachandra (2006) for this category. In the following sections we provide a brief description of the barriers, whilst Appendix A provides a more detailed description. It should be emphasised that the categorisation of hindering factors under barriers is always difficult and to some extent subjective (Weber 1997).

TABLE 1 HERE

### 2.3.1 Economic market failures

The barriers literature has strong roots in neoclassical economics. Under economic barriers, two subsets are identified: market failures and market barriers (Weber, 1997; Sorrell et al., 2000). According to neoclassical economic theory, only market failures lead to inefficient allocation of resources. Thus, government intervention is justified because it can deliver Pareto efficiency (Jaffe and Stavins, 1994). In the context of energy efficiency, a market failure would imply that more energy is being consumed for the level of service than a rational allocation of resources would justify, in light of consumers and producers preferences.

Unpriced environmental externalities tend to lower the energy cost expectations, and thus lead to lower than optimal energy efficiency improvements (Gillingham et al., 2009; Sorrell et al., 2000). Informational barriers are also market failures, since information has characteristics of a public good, i.e. many people can consume the same information with little or no extra costs (Jaffe and Stavins, 1994). Thus, actors may want to keep their information private. Under imperfect information, actors may make choices that are non-optimal and lead to lower energy efficiency improvements. For example, actors might not have adequate information on technologies and costs. Asymmetric information is a case, where one party holds more information than the other, which can lead to non-optimal energy efficiency decisions (Gillingham et al., 2000). The asymmetric information barriers identified are adverse selection, principal-agent relationship and split incentives (Sorrell et al., 2000).

### 2.3.2 Economic market barriers

Market barriers (also called non-market failures and rational behaviour) are the economic barriers that do not fall into the market failure classification; namely, risk, heterogeneity, hidden costs and access to capital. These barriers are features of the energy efficiency investment decision-making environment. For example, uncertainty related to future energy prices increases the risks of energy efficiency improvements, which decrease the level of energy efficiency measures. (Sorrell et al., 2000; Weber, 1997)

### 2.3.3 Behavioural barriers

All economic barriers are based on the assumption of rational behaviour of actors. However, as e.g. Gillingham et al. (2009) note, the true behaviour of people deviates from rationality. Behavioural barriers are considered to be behaviour that is inconsistent with utility maximisation; and whilst they have been mostly studied from individual's  perspective, firms and other organisations have similar problems but to lesser extent (Gillingham et al., 2009). Following Sorrell et al. (2000), behavioural barriers are form of information, inertia, credibility and trust, and bounded rationality. For instance inertia (i.e. resistance to change) can slow down energy efficiency improvements, because the deployment of new energy efficient technologies and ways of working requires departure from status quo. Sorrell et al. (2000) also include values as a non-barrier behavioural factor that can hinder energy efficiency, because environmental values can motivate energy efficiency improvements.

### 2.3.4 Organisational barriers

Organisational barriers are founded upon organisational theory. Within an organisation, the division of power can have impacts on energy efficiency related decisions. If the persons who are responsible for energy efficiency decisions do not have power within the organisation, this can hinder energy efficiency improvements. Culture can also be defined as a non-barrier factor that can impact energy efficiency improvements, much like personal values mentioned above. (Sorrell et al., 2000.)

### 2.3.5 Institutional barriers

Institutional barriers have been defined as barriers that are caused by political institutions (Weber, 1997). However, Sorrell et al. (2000) do not include institutional barriers in their taxonomy. The institutional barriers that have been identified include, for instance, regulatory problems and lack of policy coherence (Cagno et al., 2013; Nagesha and Balachandra, 2006).

## 2.4 Previous studies on energy efficiency barriers and energy services in Finland

Barriers for building energy efficiency in Finland have, to some extent, been studied from the building owner perspective. However, it is important to note that, to the best of our knowledge, no studies of energy efficiency barriers in Finland have utilised the taxonomies outlined above. Heiskanen et al. (2012) compiled a comprehensive literature review and study of barriers and drivers of energy efficiency from the perspective of building owners in selected EU Member States, including Finland. The barriers varied among different building owner types. In the Finnish housing sector, financial barriers among single family house owners stood out, whilst organisational barriers were significant among housing cooperatives (Heiskanen et al., 2012). For rental apartment owners, the complexity of new energy efficient solutions and their maintenance was a key barrier, while in Finland the landlord-tenant dilemma is not as large as in some countries due to a large share of well-established rental social housing providers making energy renovations easier to initiate (Heiskanen et al., 2012). Barriers concerning maintenance and management were also identified by Kyrö et al. (2012). Furthermore, municipal building owners, especially smaller municipalities suffered from lack of finance and information, whilst for office building owners the long payback periods of energy efficiency improvements were a barrier (Heiskanen et al., 2012). In addition to the above-mentioned barriers, Tuominen et al. (2012) found that there are difficulties in influencing builders' behaviour concerning energy efficiency issues and that the energy efficiency subsidies[1] in Finland are insufficient.

Barriers for energy services have been studied mainly from the ESCo business model perspective; although, as with the Finnish studies mentioned above, barrier taxonomies were not employed in the ESCo barrier studies identified. Vine (2005) studied the barriers to ESCo customers in 38 countries. The key barriers identified related to access to finance, technical and business risks, lack of understanding of the business model, access to technology and high transaction costs. Vine (2005) identified the lack of trust regarding energy efficiency equipment, ESCo organisations and services as major barriers. Marino et al. (2011) studied the ESCo markets in 39 European countries. In addition to the barriers identified in Vine (2005), the authors found that ambiguities in legislation, economic crisis, lack of standardisation, lack of collaboration and cultural issues hinder ESCo market growth. More recently, Pätäri et al. (2016) studied the barriers and drivers of ESCo business market in Finland. Whilst their findings were in-line with Marino et al. (2011) and Vine (2005), the authors did not identify any ESCO market hindering factors in laws or regulations.

[1] Multiple different types of energy subsidies have been used in Finland, with several funding cuts taking place in recent years (see full review in Kern et al., 2017). For building energy efficiency, the most relevant subsidies include energy audit support for municipalities (since 1996), subsidies for replacing oil-based heating systems (since 2003), energy grants for auditing and repair of residential buildings (since 2003), renovation aid for elderly, disabled and those on low incomes (since 2006), subsidies for efficient wood-fueled heating systems (since 2011), and renovation aid for apartment buildings (between 2013-2014)."

# 3 Research design and methods

## 3.1 Empirical case and data

IESCs in the Finnish building sector were used to study supply side barriers to energy efficiency, as integrated energy services are an emerging market in Finland. The number of IESCs is limited, in total less than 20 companies covering both new construction and renovation. In principle, IESCs can cover all building types and clients, but the current market is geared towards commercial and local authority clients owning larger commercial or public buildings. The market providing integrated energy services for residential buildings is only emerging. During 2015, fourteen semi-structured interviews were conducted with 12 companies providing integrated energy services and two cooperation organisations in the sector (thus, capturing over half of the companies in the sector). The companies were identified though internet search engines, using search words energy service (energiapalvelu), energy efficiency (energiatehokkuus) and energy saving (energiansäästö). We chose to contact only companies that provide holistic energy services for the building sector (in building level, from planning to execution) so, for example, companies providing only energy audits or certain renewable energy technologies were ruled out. The companies and were approached first by phone and subsequently by e-mail. Out of 15 interview requests, 14 accepted.

In three of the interviews, two interviewees were present, bringing the total number of interviewees to 17. The interview duration ranged from 28 to 68 minutes.  Interviews were recorded, transcribed verbatim and coded in NVivo. The interview guide (see Appendix B) did not include direct questions pertaining to barriers but relied on general questions on the status of building energy efficiency, the energy service sector and policy in Finland and specific questions about the companies' energy service business models and operation in order to prompt interviewees to spontaneously reference barriers in their discussions.

The interviewed IESCs included four large multinational companies, two Finnish medium-size companies and four Finnish small companies. Also two large Finnish companies, for whom integrated energy services were only a small part of their business were interviewed. A half of the Finnish companies sold their services also outside of Finland, mainly in the Nordic countries, the Baltics and Russia. Most of the non-exporting companies were investigating opportunities in foreign markets. The two cooperation organisations that were interviewed represent cleantech and local renewable energy businesses. Due to anonymity promised to the interviewed companies, and the number of such companies being small in Finland, we cannot disclose details about company characteristics.

All the companies interviewed provided energy services for the building sector. Typically, the most important IESC's client base was large building owners (e.g. municipalities and companies), owning other building stocks besides the residential sector including, e.g., industrial buildings, office buildings, schools and theatres. Ten companies also provided services for the housing sector, mainly for housing cooperatives and public housing, with only one company providing energy services directly to individual households. Seven companies listed services (not technical products or energy systems) as their main business on their website. For the remaining five companies, services, technical products and energy systems were equally offered on their websites.

The interviewed organisations were asked to name the most suitable interviewees for the study. Out of the 17 interviewees three were CEOs of the companies, and their backgrounds were in energy, energy efficiency and engineering. Three interviewees were working with integrated energy efficiency projects and other three with integrated energy efficiency sales. The rest of the interviewees were working e.g. with consulting, retail and energy efficiency technologies.

The companies provide a variety of services, typically, expert services such as planning, project management, project implementation, energy management, remote energy control, energy follow-up, supervision, maintenance, reporting and analyses. Five companies provided the ESCo business model among other energy services. Technical solutions that the companies provide are diverse and usually cover energy production, consumption and maintenance.

## 3.2 Actor-based analysis of supply side energy efficiency barriers

To undertake an actor-based analysis of supply side barriers, the first step was to identify the actors and actor categories in the emerging energy services ecosystem by examining the interview data. From this data we were able to map the actors in the emerging Finnish IESC ecosystem, see figure 2.

FIGURE 2 HERE

In the second step, interviewee responses were coded to identify *hindering factors* for energy performance improvements. The term 'hindering factor' has been used by Pätäri et al. (2016) to refer to the real-world examples of barriers (other terms have been used by others, such as 'problem areas' by Vogel et al. (2016)). We categorised these hindering factors in relation to the barriers taxonomy presented in Table 1.

The third step was to identify the cause-effect relationships between the hindering factors and the actors. For each hindering factor, the interviews were re-analysed to identify the actors categories that the interviewees noted as being responsible for the hindering factor and the actors affected by the hindering factor; coded as "'actor category' C" and "'actor category' A", respectively. From this coding, a matrix of hindering factors and actor categories causing and affected was built. For example, for the hindering factor 'non-functional regulation', government agencies were identified to be the cause the hindering factor that affected IESCs, builders and developers, building owners, building users, planners and architects and technology suppliers (see section 5.3 for detailed reasoning). The directional relationships were then mapped onto the business ecosystem map, to provide a visual representation (see Figures 3-5), where an arrow from an actor node indicates a causing relationship and an arrow to an actor node indicates an effect relationship. Through feedback loops, an actor can both be causing and impacted by a specific barrier.

# 4 Identification of hindering factors from the energy service company perspective

## 4.1 The emerging integrated energy service ecosystem

On the basis of the IESC interviews, a map of the emerging integrated energy service ecosystem was developed (Figure 2). Core members in the emerging ecosystem comprise the IESCs and technology supplies (hardware and software suppliers), as these actors have existing relationships built over previous projects. A key actor missing from the core businesses are downstream actors in the distribution channel; for instance, intermediaries (e.g., building centres, governmental energy agencies, etc.) that advise clients on energy services and how to participate in pilot projects. Actors in the extended ecosystem consist of technology manufactures (suppliers of suppliers), builders, developers and building owners (customers), building users (customers' customers), and building managers, planners and architects (complementators). The extended ecosystem, thus, includes the construction industry that differs from other industries due to its fragmented structure, project-based nature, high degree of specialisation, complexity and long-life-span products (Pulkka et al. 2016), and, in Finland, by the dominance of very large incumbent firms. The policy implementers, i.e. government agencies are also in the extended ecosystem due to their strong regulatory and oversight powers in the construction industry. The broader business ecosystem includes actors, such as energy producers, public bodies, trade associations, investors, unions and universities. Table 2 provides additional information on the ecosystem actors.

Based on the IESCs' interviews, we identified 29 hindering factors to energy efficiency (i.e. barriers observed in practice) that were mentioned in two or more interviews (see Tables 3-7). Those hindering factors that were mentioned in five or more interviews are explained in further detail. We have categorised the hindering factors under only one barrier category, while in practice each hindering factor may be related to more than one barrier.

TABLE 2 HERE

## 4.2 Economic market failures

Nine hindering factors were identified which relate to the barrier category economic market failures (Table 3). Factors related to information were prevalent. The most frequently mentioned hindering factors were the lack of technical skills (8 interviewees), imperfect energy efficiency building inspection (7 interviewees), imperfect policy information (6 interviewees) and imperfect cost information (5 interviewees).

TABLE 3 HERE

Lack of technical skills (n=8)

The lack of technical skills related to several different dimensions, including energy efficient building practices, building energy planning, building energy management and energy efficiency regulation, all leading to suboptimal building energy efficiency. One interviewee described the lack of technical skills in building practices in the following way:

> *The investor selects […] their own architect, heating, ventilation and air conditioning planners and other consultants. So they could, at the stage of the selection, ask "How have you, as the architect, thought the energy efficiency is going to be accomplished?" If the answer is "I have thought about putting only glass here in the south [side of the building]", alarm bells should ring,*

*since it is the cooling that costs. And even today we can see these huge facades made out of glass that are just awful from the energy performance point of view. [Interview 1]*

Imperfect energy efficiency building inspection (n=7)

IESCs noted that building inspectors—that are employed by city or municipal administration assessing whether a new or renovated building meets the requirements of the building code—do not have the proper resources to supervise the energy efficiency measures, and construction companies take advantage of this asymmetric information. For example:

> *The level of inspection is not [adequate]. This is because the building inspectors don't necessarily have the knowledge to ask for the calculations and planning that the regulations demand at the moment, even for understanding of the total building level energy performance. [Interview 3]*

Imperfect policy information (n=6)

Imperfect policy information indicates that some actors are not aware of subsidies and other policy instruments in place, and how to apply for them, whilst public sector actors have limited knowledge about approval processes. Furthermore, according to the IESCs, some public building energy efficiency improvements are neglected, because government and municipality officials are concerned that their lack of knowledge concerning relevant legislation (related to e.g. tendering) would lead to mistakes being made, for example:

> *I could mention public procurement, which in my opinion is strongly obstructive and inhibitory factor in improving energy efficiency […]; it is the knowledge of the measures that can be implemented through public procurement. There, the buyers are intimidated [by public procurement]. These energy efficiency projects are a bit more complicated to carry out than other projects, especially if financing is involved. Then [government/municipal officials] are afraid that somebody might make a mistake, if the tendering is done in a slightly wrong way, and then they would rather not do anything. [Interview 8]*

Imperfect cost information (n=5)

Imperfect cost information means that the IESCs perceive that there is a lack of knowledge regarding the real costs and benefits of energy efficiency improvements. For example, cost information might be outdated, increases in property value are not accounted for and the cost calculations are based on payback periods rather than return on capital investment.

## 4.3 Economic market barriers

Five hindering factors related to economic market barriers were identified (see Table 4). Risks were mentioned more than other barriers, with most cited hindering factor being policy risk (6 interviews).

TABLE 4 HERE

Policy risk (n=6)

Policies influencing building energy efficiency are changed frequently, creating uncertainty and difficultly for markets to cope with the changes and future uncertainty. One interviewee described the policy risk as such:

> *If you want to get subsidies, you have to apply them in January-February, after that the money has run out. Thus, you don't know if you will get the subsidies. So I would claim that the public policy has mainly slowed down the progress, because the problem is also that you don't know what will happen tomorrow. For us, it's like trying to shoot a moving target. [Interview 11]*

## 4.4 Behavioural barriers

Nine hindering factors related to behavioural barriers were identified (see Table 5). The most prevalent hindering factors mentioned were disinterest in energy efficiency improvement (8 interviews), low legitimacy (8 interviews), low priority (7 interviews), distortion in energy policy (6 interviews) and customs and practices (5 interviews).

TABLE 5 HERE

Disinterest in energy efficiency improvement (n=8)

The IESCs characterised many actors in the field as not being interested in promoting energy efficiency or developing energy efficiency solutions. Similarly, they suggested that many private sector actors (see section 4.2) are not interested in developing new business models and public bodies are often not interested in developing new practices, when it comes to energy efficiency. According to the interviews, this leads to a situation where only small incremental changes occur, at the expense of larger more systemic change.

Low legitimacy (n=7)

The IESCs perceived that their professional skills and knowledge are questioned e.g. by officials, policy makers, construction companies and building owners. In addition, the interviewees suggested that fast changes in the policy landscape have also caused the legitimacy of IESCs to be questioned; the demand for energy efficiency solutions increases rapidly when the implementation of a new policy begins, and this attracts companies that do not have the required skills for the market, which, in turn, decreases the legitimacy of IESCs. One interviewee described the phenomenon as such:

> *These on-off subsidies are completely insane; they kill the market and then create it from scratch again. Then come along the actors who don't have any continuity or experience, and in a way haven't built up the necessary competencies, who then spoil the market, because the quality varies so much that only bad experiences are created for many, which is what is remembered. [Interview 6]*

Low priority (n=7)

The low priority of energy efficiency was highlighted, with respect to construction, building energy renovations, building management and especially energy policy. Often other issues such as the energy production (nuclear or renewable) and normal business development in the construction sector have higher priority than energy efficiency, as demonstrated below:

> *Energy efficiency projects are not typically started very easily. Even in industry, very profitable investments are neglected, they see that business investments are more important than energy efficiency investments, even if energy efficiency would yield more money than developing the actual business. [Interview 7]*

Distortion in energy policy (n=6)

The interviewees raised the point that energy companies have strong political power and lobby to maintain the status quo of the energy system to protect their sunk costs, for instance:

> *In the Energy Efficiency Directive […] there is a paragraph that energy retailer companies should ensure that they do not misuse their position and hinder the energy efficiency appliance and system market formation. […] The energy efficiency law in Finland does not reflect this issue. So, in the national implementation this issue has been left unnoticed and it is clear that the energy industry lobbies for these things. [Interview 6]*

Customs and practices (n=5)

Customs and practices refer to the reluctance of actors to change their work practices and modes of operation. For example, the unwillingness of civil servants, builders, planners and building owners to change their decision-making processes or follow through on projects was raised. Traditional work practices were mentioned in multiple occasions, for example:

> *Things are done in the '80s model'. It is easy. You don't have to take a lot of risks or think about things, you just copy old plans. [Interviewee 1]*

## 4.5 Organisational barriers

Two hindering factors related to organisational barriers were identified (see Table 6). Both cases were related to culture, with the most prevalent hindering factor being non-cooperative culture (7 interviews).

Table 6 HERE

Non-cooperative culture (n=7)

The interviewees emphasised that Finnish culture is very non-cooperative and this slows down the energy service markets, as the nature of energy services requires a lot of cooperation and interactions inside organisations and between the actors. The interviewees also compared Finland to Germany and Sweden, for example:

> *There was a story in the Helsingin Sanomat newspaper that Finns go running in the forest alone, and hope that nobody sees them, and Swedish people go running in groups. So the culture is in some way different. [Interview 6]*

## 4.6 Institutional barriers

Four hindering factors related to behavioural barriers were identified (see Table 7); the most prevalent were non-functional regulation (12 interviews), lack of geographical policy coherence (4 interviews) and lack of policy coordination (4 interviews).

Table 7 HERE

Non-functional regulation (n=12)

Non-functional regulation was identified as a key factor hindering energy efficiency. For example, the interviewees noted that many policies are prepared ‘in a hurry’ and, thus, public bodies and other actors are not prepared for new policies when their implementation starts. Some policies were seen as 'too technology specific' and, thus, restrictive for the actors. According to the interviews, many policies regulate how energy efficiency improvement should be performed, as opposed to the energy efficiency outcomes. Furthermore, certain standards and requirements were seen to be obstacles rather than drivers; since they promote energy efficiency only in principle, but not in practice. One interviewee compared the building sector energy efficiency regulation to car industry:

> *Car industry is a good comparison, where the car manufacturers are required to have emissions of cars in a certain level in 2020 or 2030, so there is a long path of development, and they only have this one goal. They can reach that goal with many different strategies. But for us, there is one measure for energy certificates, one for energy audits et cetera. This blocks the strategies and the overall energy efficiency goal is blurred. [Interview 6]*

# 5 Analysis of salient hindering factors from actor perspective

To study the relationship between the barriers and the actors in the emerging energy service business ecosystem, we investigate the hindering factors that were mentioned in at least eight interviews. These are lack of technical skills, disinterest in energy efficiency improvement and non-functional regulation, detailed below.

## 5.1 Lack of technical skills

Multiple actors cause, and are affected by, the lack of technical skills that hinder energy efficiency improvements, see Figure 3. Actors that cause this hindering factor include core businesses themselves (IESCs and technology suppliers), extended ecosystem actors (builders and developers, building owners, building managers, planners and architects and planning bodies), and governmental agencies in the broader business ecosystem. Actors affected include the core businesses (IESCs and technology suppliers) alongside builders and developers, building owners, planners and architects.

On the one hand, the impact of the lack of technical skills materialises in energy efficiency projects, where the extended ecosystem actors may not have the required know-how to consider energy efficiency in their work. The lack of technical skills in public bodies and governmental agencies means that requirements and standards are not always up to date with the latest technology. Building managers' information about energy management is often limited, and, therefore, even with proper technology the resulting energy efficiency improvement can be negligible. Furthermore, building owners' lack of technical energy efficiency skills can impact the building users and their energy costs. On the other hand, the IESCs can also have limited technical skills, e.g. knowledge of new technologies, which has an impact on their customers and suppliers.

FIGURE 3 HERE

## 5.2 Disinterest in energy efficiency improvement

Disinterest in energy efficiency improvements is caused by extended ecosystem actors (government agencies, building developers, building owners and building managers) and actors in the broader ecosystem (energy companies and public bodies). The actors primarily impacted are the IESCs, the downstream building owners and building users, see Figure 4.

In practice, disinterest in energy efficiency improvements leads to a lower demand for energy services, and higher energy costs for building owners and users. The disinterest of building owners to engage in new ways of renovating and to find innovative solutions limits the possibilities for IESCs to expand their markets. Public building owners were highlighted as having a resistance to innovative development. Furthermore, the disinterest of builders and developers to demand new solutions and engage in energy efficiency enhancing practices was seen to barrier the energy service market growth and also to negatively impact the possibility of building owners to conduct energy efficient construction projects. The IESCs noted that many building managers are quite close to retirement, and their interest in professional development and undertaking new tasks is low. This has an impact on the above-mentioned technical skills as well as on how eager building owners are to improve energy efficiency. Energy companies were seen as actors with political power who benefit from the status quo, i.e. high energy consumption, hence, energy companies were not perceived to be interested in improving energy efficiency. This has an impact on energy infrastructure development as well as on political decision-making on energy efficiency.

FIGURE 4 HERE

IESCs were sometimes highlighted as actors reluctant to develop new business models to increase their market share. Since business models are often new, and the number of customers is usually limited, interest in business model innovation seems vital for the growth of IESCs. In the IESCs' ecosystem, disinterest in energy efficiency improvement was seen to negatively impact especially IESCs', building owners' and building users' energy efficiency efforts.

## 5.3 Non-functional regulation

The most prevalent hindering factor, non-functional regulation—regulations that are ineffective in practice, due to either poor design or implementation—is different than the other cases above, as it is caused by public bodies and governmental agencies, see Figure 5. Decisions concerning energy efficiency improvements made by the public bodies, especially policy implementation by public and government agencies, were perceived to be non-functional. For instance, the IESCs, builders and developers, building owners, building users, planners and architects and technology suppliers are affected by the technology restrictions, incompleteness and policy goals that do not have an effect on actual energy efficiency improvement (e.g. mandatory energy audits with no requirement for improvement actions). For building owners, these problems can cause energy efficiency renovations to be cost-inefficient.

FIGURE 5 HERE

# 6 Discussion

## 6.1 Energy efficiency hindering factors

From an integrated energy services, i.e. supply side, perspective the most prominent energy efficiency hindering factors were shown to be (1) lack of technical skills on part of a range of ecosystem actors; (2) disinterest in energy efficiency improvement again by several actors ranging from governance agencies to developers, building owners and building managers; and (3) non-functional regulation comprising both poorly designed and poorly implemented policies. The perspective of IESCs, regarding the lack of technical skills, is compatible with earlier studies in Finland (e.g. Heiskanen et al. 2012 and Tuominen et al. 2012), and is not surprising due to the rapid development of energy efficient technologies and complex nature of integrated building energy systems.

Non-functional regulation has been identified in a study of ESCo markets in 39 European countries by Marino et al. (2011). However, interestingly, our results partly differ from earlier studies of Finland. For instance, Pätäri et al. (2016) found that laws and regulations support energy service business and projects. Yet, a broader mix of energy efficiency policies can contain both poorly designed and implemented policies as well as those that drive development (Kivimaa et al. unpublished). Whilst Tuominen et al. (2012) suggest that energy efficiency subsidies in Finland are insufficient, none of the IESC interviewees mentioned lack of or insufficient subsidies as a hindering factor; only the non-functional nature of subsidies and other policy measures.

The disinterest in energy efficiency improvement has not been raised as a main barrier in other empirical studies. However, Tuominen et al. (2012) found a related aspect: a difficulty to influence builders in energy efficiency issues. In addition, challenges related to building managers' reluctance to develop energy efficiency were highlighted by Kyrö et al (2012).

One of the most salient barriers found in earlier literature (e.g. Heiskanen et al., 2012; Vine, 2005; Marino et al., 2011; Pätäri et al., 2016) was access to finance, whereas in this study only two interviewees mentioned it. However, multiple empirical barriers that emerged from this study, e.g. imperfect energy efficiency building inspection and low legitimacy of energy service companies, have not been identified in earlier empirical studies. A possible explanation for differing results may be the chosen perspective: IESCs are often newcomers in the construction or energy sector. Also, they implement energy efficiency in practice and, thus, face the empirical barriers in their everyday work. Furthermore, most previous studies have focused on demand side actors (e.g. building owners).

## 6.2 A supply side approach to analysing energy efficiency barriers

Previous theoretical endeavours into understanding energy efficiency barriers have, to a large extent, overlooked the '*whom* component' of the question proposed by Weber (1997, 834) "*What* is an obstacle to *whom* reaching *what* in energy conservation?" (emphasis in original). Whilst a demand-side perspective has been implicit in the numerous barrier models and taxonomies that have been developed over the years, only recently has empirical work (see Chai and Yeo, 2012; and Cagno et al. 2013) started to explicitly address the actors causing and affected by energy efficiency barriers. Furthermore, theoretical studies of energy efficiency barriers often remain at a conceptual level (i.e. market failures, heterogeneity, bounded rationality, etc.), while empirical studies frequently omit framing their results in any taxonomy (e.g. Tuominen et al. 2012; Heiskanen et al. 2012) or confuse hierarchies of barriers with barrier taxonomies. For example, Cagno et al. (2013) list both inertia and lack of interest in energy-efficiency, whereas we suggest lack of interest in energy efficiency to be an example of inertia. This has the effect of depoliticising energy efficiency barriers; as barriers are abstracted from the actors and their actions causing the barriers.

Specifying the hindering factors that illustrate the practical unfolding of energy efficiency barriers and identifying the actors that cause energy efficiency barriers allows us to open up the apolitical nature of earlier barriers research. By taking a supply side perspective and identifying the cause-effect relationships between practical cases of hindering factors and actors, we can better understand the root of energy efficiency barriers. For example, public bodies (e.g. the government and ministries) and government agencies (e.g. Motiva[2] and building inspection agencies) and how they interact (or don't) with other actors were seen to be the source of several hindering factors including: *imperfect policy information* (actors being unaware of subsidies or policy instruments); *imperfect energy efficiency building inspection* (lack of adequate resources and knowledge); *policy risk* (uncertainty causes by constantly changing policy goals and instruments); and *non-functional regulation* (hurried policy design and implementation leading to a lack of coordination).

By making the above barriers explicit, policymakers and civil servants (and private sector actors) should be better placed to tackle them. The building energy efficiency mix incorporates circa three dozen different policy instruments in Finland and the mix evolves continually (Kern et al. 2017). Therefore, (1) addressing imperfect policy information by increasing the awareness of such information on the part of actors, such as builders or building owners, is an extremely difficult task. This creates not only a need for government intermediaries (such as Motiva) to translate this information to a range of actors but may highlight a role for IESCs to act as policy information

[2] Motiva is an expert organisation, established in 1993, to promote efficient use of energy and later expanded to efficient use of resources. In 2000, it became a limited company, whose whole share stock is owned by the government. Most of Motiva's services are bought by the public administration.

intermediaries. (2) Addressing imperfect energy efficiency building inspection should be a priority for the government and local authority planning departments. Such a barrier has been noted to be one of the largest obstacles in the implementation of energy efficiency requirements of the building code; the most significant policy instrument perceived by the IESCs (cf. Kivimaa et al. unpublished). (3) Imperfect building inspection also contributes to non-functional regulation. (4) Policy risk caused by changing policy goals and instruments is difficult to address, because of the dual nature of policy change: on the one hand, foreseeable policy change supports innovation in the sector while, on the other hand, too frequent or abrupt changes can lead to lack of investment (Kivimaa, 2008; Kemp and Pontoglio, 2011; Kern et al., 2017). Our findings point towards the need for ensuring greater policy instrument consistency over time, coherence of policy goals (actual achievements) and policy coordination in the energy efficiency arena.

Public bodies were specifically singled out over their lack of interest in building sector energy efficiency. This was linked to the power relationships between incumbent-firm alliances (e.g. energy companies, construction firms) and public bodies. Here, the institutionalised power structures between incumbent firms and decision-makers have caused lock-ins, such as expected revenue of the government taxes and e.g. electricity sale revenues. Policies, such as energy saving obligations for energy suppliers could help to alleviate such an issue. Energy saving obligations force energy suppliers to offer energy saving services to cover a certain percentage of their energy production; thus, the energy service market is enhanced by the legislation and actors are better aligned. The Energy Efficiency Directive (EED, article 7) introduces this policy to all EU Member States. However, the EED also enables the use of alternative measures to achieve the same energy efficiency, and at least so far Finland has not implemented energy savings obligations in national legislation. Moreover, more integrated “whole-house” approaches may be less likely through supplier obligations due to higher costs of delivery (cf. Rosenow and Bayer, 2017).

## 6.3 Limitations

This study placed IESCs at the centre of the emerging energy services business ecosystem in Finland and analysed the perspective of IESCs to energy efficiency barriers. Whilst the IESCs are central actors in this study, other actors may have different views of the salient hindering factors, who causes them and who is affected by them. Furthermore, the customer types of the IESCs might have an impact on what hindering factors the companies emphasise, as Heiskanen et al. (2012) found that different building owner types have an impact on the importance of barriers. Due to the limited data set, the impact of customer type is beyond the scope of this study. However, an analysis combining the supply and demand perspectives would be an interesting future line of research. As noted in Section 2.3, the classification of energy efficiency barriers and typologies is to some degree subjective. Typologies have been "derived from theory and propelled by different concepts of action in order to remove obstacles" (Weber 1997, 834); thus, whilst energy efficiency barriers are real, they are invisible and difficult to observe.

The results portray a simplified picture of the very complex field of the emerging integrated energy services ecosystem. Not all the interviewees saw the hindering factors being played out in exactly in the same way. For instance, some were emphasising those related to informational barriers, whilst others were emphasising those related to institutional barriers. Furthermore, the most frequently mentioned hindering factors and barriers may not be the most significant ones in terms of influence. This study presents the first attempt to map the energy efficiency barriers IESCs in Finland and, hence, our primary focus was centred on barrier mapping. Additionally, the interview structure, which included many policy oriented questions, might have had an impact on the number of interviewees raising policy related hindering factors.

## 7 Conclusions and policy implications

A supply-side analysis revealed that insufficient technical skills, disinterest and non-functional regulation in energy-efficiency are the most commonly perceived hindering factors by integrated energy service companies operating in the Finnish building sector. The novelty of this study, however, was to go beyond the identification of energy efficiency barriers by analysing the relationships between barriers and actors in the emerging energy services ecosystem to understand who are causing and who are affected by the barriers.

This viewpoint allows us to take the next steps in overcoming barriers, since the actions needed can be directed to a limited number of actors and also specified to different types of actors. For instance, the results suggest that up-to-date practical information on energy efficient practices and technologies should be easily accessible to all actors to help overcome imperfect information. Energy efficiency education would be very relevant for construction sector actors to facilitate the integration of energy efficiency considerations early on into building design, planning and management as an integral part, rather than an add-on.

Non-functional regulation hinders the energy efficiency work of actors in the emerging ecosystem. Addressing this problem requires more active communication between policy makers, implementors (e.g. building inspectors) and practical actors (e.g. builders). This way the non-functionalities of policies could be brought to daylight and, in best cases, solved before the policies are implemented.

To overcome disinterest in energy efficiency improvements, the institutionalised power relationships of the actors need to be disrupted to establish a novel environment for new entrants to become more active in policy processes. For example, in many countries supplier obligations have been used to implement energy efficiency policy (e.g. Rosenow and Bayer, 2017), whereas in a new more energy efficient society, energy efficiency would be an integral part of the construction sector and addressed by actors in that sector and at the interface of energy and construction sectors. Such an approach would mean disrupting the position of incumbent energy companies—for example, by introducing policies destabilising current energy intensive practices (Kivimaa and Kern, 2016)—and increasing the political power of energy efficiency providers (e.g. IESCs). The latter could be achieved, e.g., by including new actors into energy efficiency policy working groups or better acknowledging them as valuable intermediaries translating both technical and policy information. Such an approach would also benefit from evaluating whether legal or policy barriers exist for novel integrated energy service business models to emerge, and their subsequent removal.

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